DINOFLAGELLATE CYSTS FROM THE BEARPAW FORMATION (?UPPER CAMPANIAN TO MAASTRICHTIAN) OF MONTANA

by REX HARLAND

ABSTRACT. A dinoflagellate cyst assemblage is described from the Bearpaw Formation of Montana, U.S.A. *Deflandrea montanaensis* sp. nov. is described. Archeopyle formation in *Senegalinium tricuspis* (O. Wetzel) comb. nov. is demonstrated to be of the large intercalary type, and this, together with its basic cavate morphology, allows for the recombination of the species. Also recombined are *S. magnifica* (Stanley), ?*S. albertii* (Corradini), *S. boloniensis* (Riegel), *S. gaditanum* (Riegel), ?*S. kozlowskii* (Gorka), *S. pannuceum* (Stanley), *S. pentagonalis* (Corradini), and *S. subquadratum* (Corradini). The Bearpaw Formation in Montana, on radiometric and on dinoflagellate cyst evidence is younger than that seen in southern Alberta, and may include strata encompassing the Campanian-Maastrichtian boundary.

THE Bearpaw Formation of the northern U.S.A. and Canada was deposited during the last major transgression of the Late Cretaceous sea, and before sedimentation was influenced by the growth of alluvial plains from the newly uplifted Cordillera (Stelck 1967). The base of the formation is known to be of Late Campanian age in both southern Alberta and Saskatchewan, Canada (Caldwell 1968). In Saskatchewan the formation is believed to extend into the Maastrichtian, whereas in southern Alberta it is restricted to the Campanian. A potassium-argon date of 75± 4 million years is available on a bentonite close to the base of the formation at Lethbridge, Alberta (Folinsbee *et al.* 1960, 1961), and is indicative of a Late Cretaceous age (Casey 1964; Lambert 1971).

Norton and Hall (1969) state that the Bearpaw Formation at Hell Creek, Montana, U.S.A., is Late Cretaceous in age and report a date of 70 million years from a position close to the level of their sample KB-1, i.e. close to the base of the unit as seen at Hell Creek. This suggests that the section in Montana is somewhat younger than that in southern Alberta and is probably equivalent to the upper part of the section in Saskatchewan close to, if it does not contain, the Campanian–Maastrichtian boundary, i.e. 70 m.y. or 72 m.y. (Casey 1964 and Lambert 1971 respectively). Recently Obradovich and Cobban (1975) in discussing a time-scale for the Late Cretaceous of North America suggest a 70–71 m.y. date for the Campanian–Maastrichtian boundary, but admit difficulty in defining the boundary palaeontologically. Harland (1973) following Caldwell (1968) accepted the base of the *Baculites baculus* Zone as the Campanian–Maastrichtian boundary but Obradovich and Cobban (1975) suggest it may fall as low as the base of the *B. reesidei* Zone, i.e. much of the southern Alberta Bearpaw would then be Maastrichtian. This view is not accepted here.

The present study was undertaken to describe and compare the dinoflagellate cyst assemblage from Montana with that published from southern Alberta (Harland 1973). The southern Alberta outcrop is some 230 miles north-west of the Montana section.

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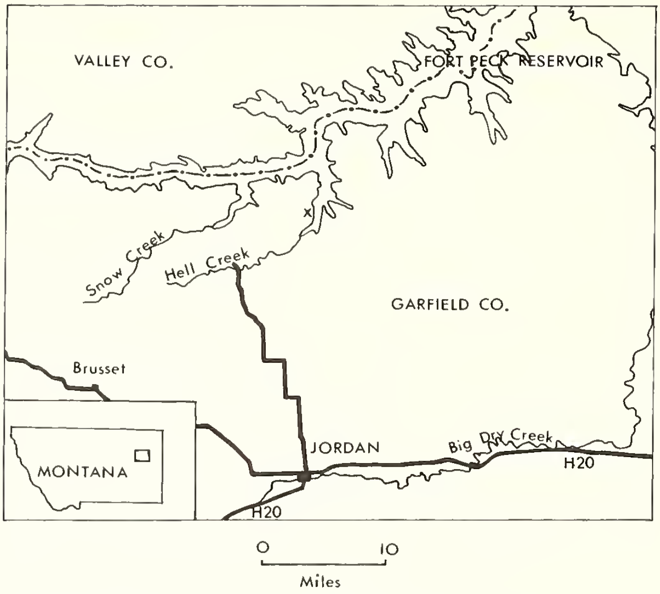
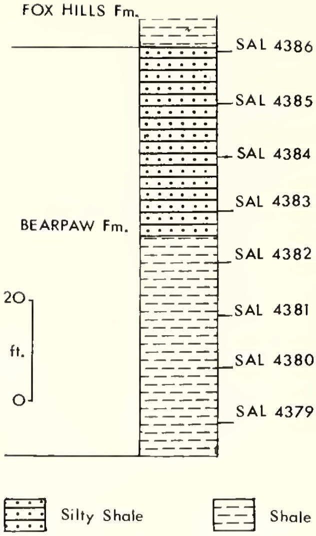


TEXT-FIG. 1. Sketch map of a part of the Fort Peck Reservoir in north-eastern Montana, U.S.A. to show the position of the sample locality (marked with an X). Bold lines indicate roads.



TEXT-FIG. 2. A stratigraphical section of the Bearpaw Formation at the Hell Creek locality showing the position of the samples.

MATERIALS AND METHODS

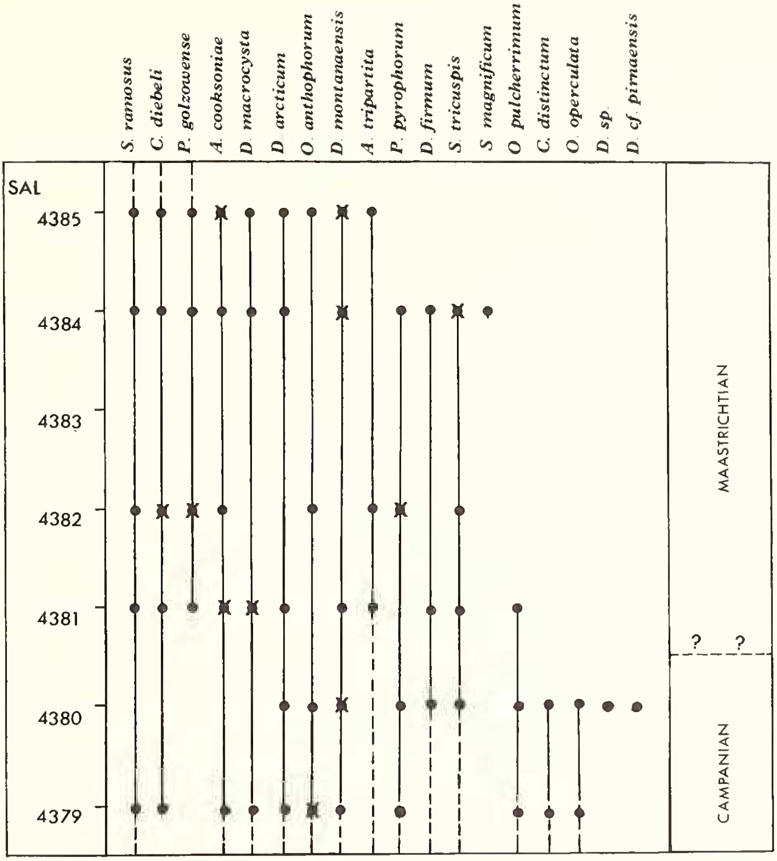
In June 1969 Drs. G. Playford, University of Queensland, Australia, and G. D. Williams, University of Alberta, Canada, collected eight samples of Bearpaw Formation from the banks of the Fort Peck Reservoir, Montana, U.S.A., i.e. locality 1 of Norton and Hall (1969). This locality (text-fig. 1) is situated some 22 miles north of Jordan on the Hell Creek part of the reservoir at S½, Sect. 31, T22N, R37E, Garfield County, Montana. At the time of collection 70 ft (21·33 m) of Bearpaw was exposed above the water level in the reservoir and beneath the overlying Fox Hills Formation. Norton and Hall (1969) described the distinct lithological change from the dark Bearpaw shale to the light-coloured shales and sandstones of the Fox Hills sandstone but no unconformity was noted. The Bearpaw Formation at this locality can be divided into a lower shale unit and an upper silty shale unit and both appear as very dark rock when freshly exposed (Norton and Hall 1969).

The sample distribution through the section is shown in text-fig. 2; the samples have been registered in the Palynological Collections of the Institute of Geological Sciences (I.G.S.) at Leeds as SAL 4379–SAL 4386. All eight samples were processed using standard palynological techniques, but beyond the hydrofluoric acid stage the residues were handled using the filtration system of Neves and Dale (1963).

Where dimensions are quoted the figure in parenthesis is the arithmetic mean of the measured morphological parameters. All illustrated material is registered in the MPK series of the palynological collections of the I.G.S. at Leeds. The ranges of species as quoted from Harker and Sarjeant (1975) are compilations from their tables in order to indicate the world-wide range.

SYSTEMATICS

The dinoflagellate cysts of this paper are placed within either a gonyaulacacean or peridiniacean grouping. It is felt that although the emended supra-generic classification of Sarjeant and Downie (1974) goes a long way to answering the criticisms of



TEXT-FIG. 3. The range of species through the Bearpaw Formation at the Hell Creek locality, Fort Peck Reservoir, Montana, showing the possible Campanian–Maastrichtian boundary. Range of species that are known to be greater than that as proved at Hell Creek are shown by a broken line. The large dots represent the presence of a species within the sample indicated, and the crosses indicate an occurrence of greater than 10% of the dinoflagellate cyst population.

Wall and Dale (1968) there are too many new forms being described and too much taxonomic revision to use it or any other formal supra-generic classification at the present time. This is particularly true of deflandreoid cysts where detailed knowledge of their morphology, particularly archeopyle formation, is still lacking. There is, however, no question that at least two major groupings can be recognized amongst fossil dinoflagellate cysts and these are used here; the Gonyaulacaceae and the Peridiniaceae.

Division PYRRHOPHYTA Pascher
Class DINOPHYCEAE Pascher
Order PERIDINIALES Lindemann

GONYAULACACEAN GROUP

Genus CYCLONEPHELIUM Deflandre and Cookson emend. Williams and Downie 1966

Type species. Cyclonephelium compactum Deflandre and Cookson, 1955; O.D.

Cyclonephelium distinctum Deflandre and Cookson, 1955

Plate 25, fig. 14

1955 *Cyclonephelium distinctum* Deflandre and Cookson, pp. 285–286, pl. 2, fig. 14; text-figs. 47, 48.

Figured material. Slide SAL 4381-RH1, specimen MPK 917.

Remarks. Only a few specimens were found in the lower part of the sequence and the illustrated form falls at the smaller end of the size range of this species as quoted by Harland (1973). Sarjeant (1967*a*) gives a Hauterivian to Santonian range for this species but it is now known from the Campanian (Clarke and Verdier 1967; Harland 1973) and from the ?Maastrichtian (McIntyre 1974). Harker and Sarjeant (1975) record a range of Berriasian to ?early Palaeocene.

Genus DICTYOPYXIDIA Eisenack, 1961

Type species. Dictyopyxidia areolata (Cookson and Eisenack) Eisenack and Kjellström, 1971; O.D.

Dictyopyxidia sp.

Plate 25, fig. 15

Figured material. Slide SAL 4380-RH1, specimen MPK 918.

Remarks. This appears to be a new species but because only a single specimen was observed its formal description is not attempted. It is closely comparable to *D. circulata* Clarke and Verdier, 1967 but does not appear to have the complexity of fields or the rounded ambitus of that species. It was found towards the base of the section.

Genus OLIGOSPHAERIDIUM Davey and Williams, 1966

Type species. Oligosphaeridium complex (White) Davey and Williams, 1966; O.D.

?*Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey, 1969

1958 *Hystrichosphaeridium anthophorum* Cookson and Eisenack, pp. 43–44, pl. 11, figs. 12, 13; text-figs. 16–18.
1969 *Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey, pp. 147–148, pl. 5, figs. 1–3.

Remarks. This species was observed throughout the section. Its range, noted as ?Oxfordian to Albian by Sarjeant (1967*a*), is now known to be at least into the ?Maastrichtian (McIntyre 1974), and Harker and Sarjeant (1975) indicate a Berriasian to ?early Oligocene range. It is quite possible, however, that the present assignment is incorrect, as the Jurassic forms, probably like the holotype, have solid processes (R. J. Davey pers. comm. 1975) whereas these and other Upper Cretaceous forms have hollow processes. This species could, therefore, benefit from restudy and it is quite likely that these and other Late Cretaceous forms are a separate, possibly new, species.

Oligosphaeridium pulcherrimum (Deflandre and Cookson) Davey and Williams, 1966

1955 *Hystrichosphaeridium pulcherrimum* Deflandre and Cookson, pp. 270–271, pl. 1, fig. 8; text-figs. 21, 22.
1966 *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams, pp. 75–76, pl. 10, fig. 9; pl. 11, fig. 5.

Remarks. This form was recorded from the lower part of the sequence but its range (Sarjeant 1967*a*) is Valanginian to lower Eocene. It was recorded from the Bearpaw of southern Alberta (Harland 1973) and more recently from the Campanian and Maastrichtian of Arctic Canada (McIntyre 1974). Harker and Sarjeant (1975) indicate a ?Jurassic to ?middle Eocene range; middle Albian to late Campanian in North America.

Genus SPINIFERITES Mantell emend. Sarjeant 1970

Type species. Spiniferites ramosus (Ehrenberg) Mantell, 1854; S.D. by Loeblich and Loeblich 1966.

Spiniferites ramosus (Ehrenberg) Mantell, 1854

1838 *Xanthidium ramosum* Ehrenberg, pl. 1, figs. 1, 2, 5.
1854 *Spiniferites ramosus* (Ehrenberg) Mantell, p. 239, Lign 77, fig. 4.

Remarks. Specimens of this species complex were recorded in all the samples studied. *S. ramosus* has a Berriasian to Recent stratigraphic range (Harker and Sarjeant 1975).

PERIDINIACEAEN GROUP

Genus AUSTRALIELLA Vozzhennikova, 1967

Type species. Australiella tripartita (Cookson and Eisenack) Vozzhennikova, 1967; O.D.

Australiella cooksoniae (Alberti) Vozzhennikova, 1967

Plate 25, fig. 9

1959 *Deflandrea cooksoni* Alberti, 97–98, pl. 9, figs. 1–6.
1967 *Australiella cooksoni* (Alberti) Vozzhennikova; 132, pl. LXI, figs. 1–4.

Figured material. Slide SAL 4385-RH1, specimen MPK 919.

Remarks. Specimens of this species occur throughout the studied sequence. Its recorded range (Sarjeant 1967*a*) is Santonian to Campanian. McIntyre (1974) recorded a form he referred to as *Deflandrea* sp. cf. *D. cooksoni* from the ?Maastrichtian, and Zaitzeff and Cross (1970) have also recorded it from the Maastrichtian. The form described as *D. korojonensis* Cookson and Eisenack by Harland (1973) should more correctly be assigned here. Harker and Sarjeant (1975) give an ?early Cenomanian to early Palaeocene age for this species.

Australiella tripartita (Cookson and Eisenack) Vozzhennikova, 1967

1960 *Deflandrea tripartita* Cookson and Eisenack, 2, pl. 1, fig. 10.
1967 *Australiella tripartita* (Cookson and Eisenack) Vozzhennikova, pp. 134–135, pl. LXI, fig. 1; pl. LXIV, figs. 1–4.

Remarks. This species was observed throughout the section. Its previously recorded range (Sarjeant 1967*a*) was Turonian to Campanian, so the present observation may indicate an extension into the lowermost Maastrichtian in North America. Harker and Sarjeant (1975) recently gave an ?early Cenomenian to ?late Maastrichtian range.

Genus CERATIOPSIS Vozzhennikova, 1963

Type species. *Ceratiopsis leptoderma* Vozzhennikova, 1963; O.D.

Ceratiopsis diebeli (Alberti) Vozzhennikova, 1967

Plate 25, fig. 16

1959 *Deflandrea diebeli* Alberti, 99–100, pl. 9, figs. 18–21.
1967 *Ceratiopsis diebeli* (Alberti) Vozzhennikova, pp. 159–160, pl. CXIX, fig. 4.

Figured material. Slide SAL 4384-RH1, specimen MPK 920.

Remarks. This species was found throughout the sequence and had a previously recorded range of Santonian to Campanian (Sarjeant 1967*a*), it is now known from the Maastrichtian and Danian (Wilson 1971). Harker and Sarjeant (1975) indicate a ?late Coniacian to late Eocene range.

Genus DEFLANDREA Eisenack emend. Williams and Downie 1966

Type species. *Deflandrea phosphoritica* Eisenack, 1938; O.D.

Deflandrea macrocysta Cookson and Eisenack, 1960

1960 *Deflandrea macrocysta* Cookson and Eisenack, 3, pl. 1, figs. 7, 8.

Remarks. *D. macrocysta* is found throughout the section. Sarjeant (1967*a*) and Harker and Sarjeant (1975) recorded a restricted Campanian range for this species so that the present study may indicate a slight extension into the lowermost Maastrichtian.

Deflandrea montanaensis sp. nov.

Plate 25, figs. 4, 6, 7, 10–12

Diagnosis. Cavate cyst, epitract conical, hypotract hemispheroidal with an asymmetrical 'skirt' and horn. Endoblast elongated apically and hemispheroidal antapically. Wall layers smooth. Apex surmounted by a bifid tip; the larger antapical horn acuminate. Tabulation discernible but not usually recognizable, delimited by low, smooth, or poorly denticulate ridges. Cingulum planar, may or may not be slightly indented; sulcus large and broad, widening towards the antapex. Archeopyle intercalary in periphragm and endophragm; commonly attached Ia/Ia (Evitt 1967), and apically/antapically elongate hexagonal in shape.

Figured material. Holotype: Slide SAL 4380-RH1, specimen MPK 921, Bearpaw Formation, ?Campanian to Maastrichtian, Montana, U.S.A. Paratypes: Slide SAL 4380-RH2, specimens MPK 922–924.

Dimensions. Holotype: length 35·0 μ, breadth 16·25 μ. Range: length 18·75 (27·50) 36·25 μ, breadth 8·75 (17·0) 25·00 μ. Twelve specimens were measured from a studied population of twenty-five.

Description. A diamond-shaped to elongate fusiform cyst made up of the two wall layers that are only adpressed in the cingular region and on the upper part of the hypotract. The epitractal periphragm is drawn out into an apical horn which carries a dorso-ventrally flattened, bifid tip. The antapical 'skirt' and horn sometimes carry small, poorly developed, irregular spines, especially on the margin of the 'skirt'. The tabulation is variously developed but difficult to decipher, it is probably ?4′, 1a, ?7″, 6c, ?‴, ?2⁗. The cingulum is divided into six well-defined cingular plates. Archeopyle is formed by a single opening through the periphragm and endophragm and the operculum appears to remain attached (Pl. 25, fig. 10), type Ia/Ia of Evitt (1967).

Remarks. This cyst is closely comparable to *Spinidinium clavum* Harland, 1973 (see below for further comments), and it is possible that a full range of variation exists between the two forms. This was not seen to be the case, however, in either the present assemblage or in southern Alberta (Harland 1973), and therefore it is regarded as a distinct and separate species. It occurs throughout the studied section.

Comparisons. This cyst is closely comparable to *D. minor* Alberti, 1959 from which it differs in over-all shape, *D. minor* being more rhomboidal and having a condensed endoblast, and in possessing a tabulation. It is also comparable with *D. balmei* Cookson and Eisenack, 1962 which again differs in form, in the amount of endoblastic 'contraction' and in possessing spines. It is closest to *S. clavum* Harland, 1973 but differs in not possessing high, denticulate, sutural crests and in being much smaller, i.e. nearly half the size. It may be an evolutionary descendant of that species. It is also closely comparable to *S. rallum* Heisecke, 1970, *D. irmoechinata* Heisecke, 1970, and *D. rhombica* Cookson and Eisenack, 1974, all of which, however, differ in possessing numerous well-developed spines.

Deflandrea cf. *pirnaensis* Alberti, 1959

Plate 25, fig. 8

1959 *Deflandrea pirnaensis* Alberti, p. 100, pl. 8, figs. 1–5.

Figured material. Slide SAL 4381-RH1, specimen MPK 925.

Remarks. The single specimen encountered is most closely comparable to *D. pirnaensis*, which had a previously published range of Albian to Coniacian (Sarjeant 1967*a*). Harker and Sarjeant (1975) indicate a late Hauterivian to late Maastrichtian range.

Genus DICONODINIUM Eisenack and Cookson, 1960

Type species. Diconodinium multispinum (Deflandre and Cookson) Eisenack and Cookson, 1960; O.D.

Diconodinium arcticum Manum and Cookson, 1964

1964 *Diconodinium arcticum* Manum and Cookson, pp. 18–19, pl. 6, figs. 1–4.

Remarks. D. arcticum occurs throughout the sequence. Its previously recorded range

(Manum and Cookson 1964) was early late Cretaceous which has now been ascertained by Felix and Burbridge (in press) to be a late Cenomanian to early Campanian age. The present evidence and also that of McIntyre (1974) suggests an extension of the range into the ?Maastrichtian. Harker and Sarjeant (1975) indicate an early Cenomanian to late Campanian range.

Diconodinium firmum Harland, 1973

1973 *Diconodinium firmum* Harland, pp. 669–670, pl. 84, figs. 8, 9, 15; text-fig. 6.

Remarks. This form was found almost throughout the sequence. Its previous range was late Campanian (Harland 1973) so that its range may be increased into the ?earliest Maastrichtian (herein and McIntyre 1974). Zaitzeff and Cross (1970) recorded *Diconodinium* sp. 1 which is probably synonymous to *D. firmum* from the Maastrichtian of Texas. After checking the original and comparable specimens of this species (all specimens illustrated in Harland (1973) are now held by the I.G.S. in Leeds) it is thought to have an archeopyle like that illustrated by McIntyre (1975) for his genus *Laciniadinium*, but since some doubt remains a formal recombination is not attempted here.

Genus PALAEOCYSTODINIUM Alberti, 1961

Type species. Palaeocystodinium golzowense Alberti, 1961; O.D.

Palaeocystodinium golzowense Alberti, 1961

Plate 25, fig. 13

1961 *Palaeocystodinium golzowense* Alberti, p. 20, pl. 7, figs. 10–12; pl. 12, fig. 16.

Figured material. Slide SAL 4381-RH1, specimen MPK 926.

Remarks. P. golzowense is confined to samples above SAL 4380. Its previously recorded range (Sarjeant 1967*a*) was Eocene to Oligocene but it has also been

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EXPLANATION OF PLATE 25

All figures are at a magnification of ×500 unless otherwise stated and were photographed using phase contrast techniques.

Fig. 1. *Palaeoperidinium pyrophorum* (Ehrenberg) Deflandre, MPK 927, dorsal view showing over-all morphology, faint growth lines and slight rupture of the epitract along the cingulum.

Fig. 2. *Senegalinium magnificum* (Stanley) comb. nov., MPK 928, specimen showing the large, single reflected plate archeopyle and the small pericoels.

Figs. 3, 5. *Senegalinium tricuspis* (O. Wetzel) comb. nov., MPK 929, 930, fig. 3 showing the large intercalary archeopyle.

Figs. 4, 6, 7, 10–12. *Deflandrea montanaensis* sp. nov., MPK 921, 922, 923, 924, figs. 4, 7, holotype, figs. 4, 6, ×1000, specimens showing range of variation and over-all morphology.

Fig. 8. *Deflandrea* cf. *pirnaensis* Alberti, MPK 925.

Fig. 9. *Australiella cooksoniae* (Alberti) Vozzhennikova, MPK 919.

Fig. 13. *Palaeocystodinium golzowense* Alberti, MPK 926, specimen showing the intercalary archeopyle.

Fig. 14. *Cyclonephelium distinctum* Deflandre and Cookson, MPK 917.

Fig. 15. *Dictyopyxidia* sp., MPK 918.

Fig. 16. *Ceratiopsis diebeli* (Alberti) Vozzhennikova, MPK 920.

HARLAND, Campanian–Maastrichtian dinoflagellates from Montana recorded from the Maastrichtian to ?Palaeocene (Malloy 1972). Harker and Sarjeant (1975) record an early Maastrichtian to late Oligocene range.

Genus PALAEOPERIDINIUM Deflandre, 1934

Type species. Palaeoperidinium pyrophorum (Ehrenberg) Deflandre, 1935, emend. Sarjeant 1967*b*; S.D.

Palaeoperidinium pyrophorum (Ehrenberg) Deflandre, 1935, emend. Sarjeant 1967*b*

Plate 25, fig. 1

1838 *Peridinium pyrophorum* Ehrenberg, pl. 1, figs. I, IV.
1967*b* *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant, pp. 246–247, figs. 1–6.

Figured material. Slide SAL 4379-RH1, specimen MPK 927.

Remarks. This cyst is found throughout the studied section. Its previously recorded range was Coniacian to Maastrichtian (Sarjeant 1967*a*) and now Harker and Sarjeant (1975) give it an ?early Coniacian to ?early Palaeocene range.

Genus SENEGALINIUM Jain and Millepied, 1973

Type species. Senegalinium bicavatum Jain and Millepied, 1973; O.D.

Remarks. The view of Herngreen (1975) on the status of *Senegalinium* is not accepted here. Unfortunately Jain and Millepied (1973) did not stress the mode of archeopyle formation in their original description of *Senegalinium* which is characteristic and unique to this genus, i.e. possessing a large, single plate, elongate hexagonal intercalary archeopyle which almost gives the impression of being precingular.

Senegalinium magnificum (Stanley) comb. nov.

Plate 25, fig. 2

1965 *Deflandrea magnifica* Stanley, pp. 218–219, pl. 20, figs. 1–6.

Figured material. Slide SAL 4383-RH1, specimen MPK 928.

Remarks. This species is herein recombined into *Senegalinium* as it possesses the large intercalary single-plate archeopyle and the small pericoels characteristic of the genus. It was recorded from a single sample in the Montana section. It had a Palaeocene range (Sarjeant 1967*a*) but Kjellström figured it as *Lejeunia hyalina* from the Maastrichtian (fig. 1 of Kjellström 1972) and this is probably confirmed herein. Zaitzeff and Cross (1970) also have recorded it from the Maastrichtian. Harker and Sarjeant (1975) record the range as early Santonian to early Eocene.

Senegalinium tricuspis (O. Wetzel) comb. nov.

Plate 25, figs. 3, 5

1933*b* *Peridinium tricuspis* O. Wetzel, 166, pl. 2, fig. 14.
1970 *Astrocysta tricuspis* (O. Wetzel) Davey, p. 360.
1973 *Lejeunia tricuspis* (O. Wetzel) Harland, p. 673, pl. 84, fig. 4.

Figured material. Slides SAL 4380-RH1 and SAL 4381-RH1, specimens MPK 929, 930.

Remarks. This species was observed to possess a large intercalary archeopyle (Pl. 25, fig. 3) and together with the small pericoels developed in the regions of the apical and antapical horns indicate its affinities to this genus and not to the genus *Astrocysta* Davey whose archeopyle is now known to be transapical (Norris and Hedlund 1972). *S. tricuspis* occurs almost throughout the studied section and indeed Sarjeant (1967*a*) and Harker and Sarjeant (1975) have recorded a Santonian to Maastrichtian range for the species.

Other species. The following species also belong to this genus: ?*S. albertii* (Corradini, 1972) comb. nov. = *Deflandrea albertii* Corradini, 1972, pp. 174–175, pl. 27, figs. 7*a*, *b*, 8; pl. 28, fig. 2. *S. boloniensis* (Riegel, 1974) comb. nov. = *D. boloniensis* Riegel, 1974, pp. 354–356, pl. 1, figs. 6–10; text-figs. 3, 4. *S. gaditanum* (Riegel, 1974) comb. nov. = *D. gaditana* Riegel, 1974, pp. 356–357, pl. 2, figs. 8, 9; pl. 3, figs. 1–2. ?*S. kozlowskii* (Gorka, 1963) comb. nov. = *Lejeunia kozlowskii* Gorka, 1963, p. 41, pl. 5, fig. 4. *S. pannuceum* (Stanley, 1965) comb. nov. = *D. pannucea* Stanley, 1965, p. 220, pl. 22, figs. 1–4, 8–10. *S. pentagonalis* (Corradini, 1972) comb. nov. = *D. pentagonalis* Corradini, 1972, p. 175, pl. 28, fig. 3. ?*S. subquadratum* (Corradini, 1972) comb. nov. = *D. subquadra* Corradini, 1972, pp. 175–176, pl. 28, fig. 1.

GROUP UNCERTAIN

Genus ODONTOCHITINA Deflandre emend. Davey 1970

Type species. Odontochitina operculata (O. Wetzel) Deflandre and Cookson, 1955; O.D.

Odontochitina operculata (O. Wetzel) Deflandre and Cookson, 1955

1933*a* *Ceratium* (*Euceratium*) *operculatum* O. Wetzel, p. 170, pl. 2, figs. 21, 22; text-fig. 2.
1955 *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson, pp. 291–292, pl. 3, figs. 5, 6.

Remarks. This species was found in the lowermost part of the section. Its previously recorded range was Hauterivian to Campanian (Sarjeant 1967*a*), but McIntyre (1974) recorded it from the ?Maastrichtian, as did Zaitzeff and Cross (1970) but as *O. striatoperforata* (see Williams 1974). Harker and Sarjeant (1975) give this species a range of early Valanginian to late Maastrichtian.

COMPARISON AND INTERPRETATION

The dinoflagellate cyst assemblage recovered from the Bearpaw Formation of Hell Creek, Montana contains a number of forms in common with the same formation in southern Alberta (Harland 1973). These are *Cyclonephelium distinctum* Deflandre and Cookson, *Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey, *O. pulcherrimum* (Deflandre and Cookson) Davey and Williams, *Spiniferites ramosus* (Ehrenberg) Mantell, *Australiella cooksoniae* (Alberti) Vozzhennikova = *Deflandrea korojonensis* Cookson and Eisenack of Harland (1973), *A. tripartita* (Cookson and Eisenack) Vozzhennikova, *D. macrocysta* Cookson and Eisenack, *Diconodinium arcticum* Manum and Cookson, *D. firmum* Harland, *Senegalinium tricuspis* (O. Wetzel) comb. nov., and *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson. Species that are exclusive to the Montana section are *Dictyopyxidia* sp., *Ceratiopsis diebeli* (Alberti) Vozzhennikova, *Deflandrea montanaensis* sp. nov., *D.* cf. *pirnaensis* Alberti, *Palaeocystodinium golzowense* Alberti, *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant, and *S. magnificum* (Stanley) comb. nov. The Montana section contains seventeen species of dinoflagellate cysts as compared to the fifty-three recorded from southern Alberta; eleven species are in common. In the terms of the categories of relative proportions as given by Harland (1973), *Oligosphaeridium anthophorum*, *A. cooksoniae*, *Ceratiopsis diebeli*, *D. macrocysta*, *D. montanaensis*, *Palaeocystodinium golzowense*, and *S. tricuspis* are 'occasionally common', i.e. making up greater than 10% of the dinoflagellate cyst population on occasions, with the remainder being 'rare'. No species was 'common' throughout the Montana section.

It is now possible to compare the described assemblage with those of Zaitzeff and Cross (1970), Jain and Millepied (1973), Riegel (1974), and McIntyre (1974), especially with regard to *Australiella*, *Diconodinium*, and *Senegalinium*. It is also possible to comment that the present assemblages, together with Harland (1973) and the publications mentioned above, differ from those of Clarke and Verdier (1967) and Wilson (1971), especially with regard to the presence of species belonging to *Diconodinium* and *Senegalinium*. They are comparable, however, in the presence of *Australiella* species and of *Odontochitina operculata*. Some provincialism may be indicated or differences may be caused by local facies or palaeoenvironments. Certainly the northern United States and Canadian assemblages, of this age indicate a single water body during the Late Cretaceous.

A major reason for the differences between the sections and assemblages from southern Alberta and Montana is age. The three species *C. diebeli*, *P. golzowense*, and *S. magnificum* are all much better known from the Maastrichtian than the Campanian, and on plotting the recovered species from the Montana section and including their known stratigraphical ranges in North America (see text-fig. 3) an apparent change in the assemblage occurs at about the level of sample SAL 4380 with no apparent change in the lithology. Here an assemblage with *O. operculata*, *Oligosphaeridium pulcherrimum*, and *Cyclonephelium distinctum* gives way to one containing *Ceratiopsis diebeli*, *P. golzowense*, and *S. magnificum*. Can this be considered as the Campanian–Maastrichtian boundary?

Unfortunately the full results of Wilson's study on the European type Campanian and Maastrichtian stages, preliminarily reported upon in 1971, are not yet published. It would appear, however, that *Odontochitina operculata* has a top at the Campanian–Maastrichtian boundary or just within the earliest Maastrichtian, and that *C. diebeli* is commonly first found in the Maastrichtian (Wilson 1971). There is therefore some evidence for placing the Campanian–Maastrichtian boundary at the level of SAL 4380 and also evidence for regarding the whole section as being Maastrichtian in age. An age assignment of very latest Campanian to Maastrichtian or entirely Maastrichtian may, therefore, be given to the section at Hell Creek in Montana. Evidence from the radiometric data available and the radiometric time scale, as understood at present, appears to support the dinoflagellate biostratigraphy. However, errors are inherent in the construction of such a time scale and the delimitation of absolute time for stage boundaries (see Obradovich and Cobban 1975); but it is interesting that there is some correspondence.

The Bearpaw sea in Montana at this time was probably shallow and under a terrigenous influence, because there is a low proportion of dinoflagellate cysts in the total palynomorph content (only between 1–15% throughout the section), a low species diversity, and a high proportion of peridiniacean to gonyaulacacean cysts (see Harland 1973). This is in contrast to the southern Alberta sections where there were larger and more diverse populations of dinoflagellate cysts, probably reflecting better palaeoenvironmental conditions. Since the formation in Montana is younger than that in Alberta it is likely to be reflecting the growing influence of continental sedimentation.

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